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ABSTRACT

Thirty-two computer-based lesson modules in organic chemistry were developed at the University of Texas (Austin) over an 18-month period and evaluated in varying classroom situations for three semesters starting in the Fall of 1972. The modules were designed as supplements to the traditional organic chemistry course of the University. As such, they emphasized tutorial-drill and experiment simulation applications in some of the basic organic chemistry concepts including nomenclature, classes of organic compounds, syntheses, reactions, preparations, laboratory exercises, and spectral interpretations. This paper includes descriptions of the modules together with a summary of their initial use and evaluation. (Author/DGC)

The Use of Computer-based Instruction

in Undergraduate Organic Chemistry

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This paper is based upon the Final Report of the Organic Chemistry Project to Project C-BE, sponsored by the National Science Foundation and the University of Texas at Austin.

I. DESCRIPTION OF THE PROJECT

A total of thirty-two computer-based lessons (modules) in organic chemistry were developed over an 18 month period and evaluated in varying classroom situations for three consecutive semesters starting in the Fall, 1972. Of the thirty-two lessons, ten were developed directly under Project C-BE. The lessons are listed in Table I. A description of each of the lessons may be obtained from the author.

Traditionally, organic chemistry courses of the University of Texas consist of three 50-minute lectures and one 4-hour laboratory per week. The modules were designed as supplements to the traditional organic chemistry course. As such, they emphasized tutorial-drill and experiment simulation applications in some of the basic organic chemistry concepts including nomenclature, classes of organic compounds, syntheses, reactions, preparations, laboratory exercises, and spectral interpretations. These concepts often transcend a given instructional strategy or textbook format. That is, the design of the modules was such that an instructor could use them with a variety of organic chemistry course designs or textbooks.

Accordingly, the lessons were used by the same instructor in varying course designs over the three-semester evaluation period. These designs are described in the following section.

Table I.

COMPUTER-BASED LESSONS IN ORGANIC CHEMISTRY

SIMULATED EXPERIMENTS

AND

TUTORIAL-DRILL APPLICATIONS

COURSE: ORGANIC

LESSON	AREA
OCH1	Alkane Nomenclature
OCH2	Alkene Nomenclature
OCH3	Alcohol, Aldehyde, Ketone Nomenclature
OCH4	Benzene Derivative Nomenclature
OCH5	General Nomenclature Quiz
OCH6	Organic Syntheses (Electrophilic Aromatic)
OCH7	Organic Syntheses (Electrophilic Aromatic)
OCH8	Kinetics of a Reaction (S)
OCH9	Interpretation of Kinetic Data (S)
OCH10	Alkene Reactions and Preparations
OCH11	Arene Preparations and Reactions
OCH12	Alcohol Preparations and Reactions
OCH13	General Reaction Quiz
OCH14	Alcohol Dehydration (S)
OCH15	Optical Rotation Measurements (S)
OCH16	Valence Bonding and Organic Compounds
OCH17	Alkene Related Syntheses
OCH18	Halogenation Mechanism
OCH19	Electrophilic Substitution Mechanism
*OCH20	General Synthetic Problems
OCH21	A Fast Review of Alkene Reactions
OCH22	Separation of a 2-Component Organic Mixture
*OCH24	Basics of Stereochemistry
OCH25	Organic Qualitative Analysis
*OCH26	Aldehydes and Ketones: Reactions and Preparations
*OCH28	Amines: Reactions and Preparations
*OCH29	Phenols: Reactions and Preparations
*OCH30	Diazonium Salts: Reactions
*OCH31	Organic Laboratory Experiments: Reporting the Results
*OCH32	Elementary NMR Interpretations.
*OCH33	Elementary IR Interpretations
*OCH34	General Classes of Organic Compounds

(S) = Simulated Experiment

* Developed under Project C-BE

II. DESCRIPTION OF THE STUDENT POPULATION AND COURSE DESIGN

Fall Semester 1972

The original course enrollment for the experimental class numbered 103 students; 73 students completed the course. The students were chemistry or chemical engineering majors.

The design of the experimental course differed from the traditional course described above in several respects. The number of formal lecture sections was decreased from three to two 50-minute meetings per week. The time normally reserved for the third meeting was designated as an optional discussion period. Twenty-one computer-based lessons (average length approximately 35 minutes each (Table II)) were assigned as a required part of the course. Students scheduled their computer interactions at times convenient to their own schedules and used

Table II

Assigned Computer Lessons for Experimental Section of Chemistry 818a.

	Name	Area
1.	OCH16	Valence Bonding and Organic Compounds
2.	OCH34	Classes of Organic Compounds
3.	OCH1	Alkane Nomenclature
4.	OCH22	Separation via Extraction
5.	OCH18	Chlorination of Propane
6.	OCH24	Basics of Stereochemistry
7.	OCH2	Alkene Nomenclature
8.	OCH14	Dehydration of 2-Methylcyclohexanol
9.	OCH10	Preparations and Reactions of Alkenes
10.	OCH31	Reporting Laboratory Results
11.	OCH17	Elementary Alkene-related Syntheses
12.	OCH14	Arene Nomenclature
13.	OCH19	Mechanism of Electrophilic Aromatic Substitution; Orientation; Reactivity
14.	OCH11	Preparations and Reactions of Arenes
15.	OCH6	Elementary Aromatic Syntheses
16.	OCH7	Aromatic Syntheses
17.	OCH3	Alcohol, Aldehyde, Ketone Nomenclature
18.	OCH12	Preparations and Reactions of Alcohols
19.	OCH29	Preparations and Reactions of Phenols
20.	OCH32	Elementary NMR Interpretations
21.	OCH33	Elementary IR Interpretations

standard teletype consoles. The lessons were written in CLIC (Conversational Language for Instructional Computing), an interactive computer language developed by personnel of the University of Texas Computation Center and designed for the University of Texas CDC 6400-6600 system. A minimum level of achievement of 85 percent was established for most of the lessons. Until this level was attained, the student received no credit for the lesson interaction, but was allowed to repeat the interaction without penalty until a satisfactory performance was demonstrated. The regularly assigned laboratory periods were not modified.

Spring Semester 1973:

Forty-four students enrolled in the second semester course taught by the same instructor of the first semester experimental course. Thirty-four students completed the course.

Due to a fewer number of computer-based instructional materials that were related to the content of the course, the design of the second semester course was more toward the traditional method and included three 50-minute lecture sessions and one 4-hour laboratory per week. The computer lessons listed in Table III were a required portion of the course.

Table III

Assigned Computer Lessons for the Experimental Section of Chemistry 818b

	Name	Area
1.	OCH5	General Nomenclature Quiz
2.	OCH14	General Reaction Quiz
3.	OCH12	Alcohol Preparation and Reactions
4.	OCH26	Aldehydes and Ketones: Reactions and Preparations
5.	OCH28	Amines: Reactions and Preparations
6.	OCH29	Phenols: Reactions and Preparations
7.	OCH30	Diazonium Salts: Reactions
8.	OCH32	Elementary NMR Interpretations

Fall Semester 1973:

Of the 79 students initially enrolled in the course, 60 completed the semester. The instructor was the same as for the two previous experimental courses conducted in the 1972-73 academic year.

The design of the course was essentially that of the traditional course described in Section I above, with the exception that the computer-based lessons listed in Table II above were required supplements. A lower minimum achievement level, 70 percent, was set for the lessons. As in the previous experimental courses, the students were Chemistry or Chemical Engineering majors.

III. RATIONALE FOR TESTS USED AS ASSESSMENTS

In that the modules were designed around several of the basic concepts inherent in the instruction of organic chemistry, regularly scheduled examinations would contain questions related to the stated objectives of the computer-based lessons. If the modules were effective, then it was assumed that this effectiveness would be reflected in the overall performance of the students.

The tests used to measure the effectiveness of the modules were the regularly scheduled hour examinations and the final examination for the organic chemistry course. The decision to follow this form of evaluation strategy was based upon the previously documented effectiveness of computer-based instruction in organic chemistry using modules of similar design and content (1,3,4).

In addition, student evaluation forms were administered to each of the classes.

IV. EVIDENCE OF EFFECTIVENESS

The semester grade distributions for the three experimental classes are shown in Table IV.

Table IV

Semester Grade Distributions for

Experimental Classes in Organic Chemistry (%)

Class		A	B	C	D	F
Fall 72	N=73	16	23	33	22	5
Spring 73	N=34	25	21	37	17	0
Fall 73	N=60	22	25	27	25	1

Although the grade distributions do not indicate any outstanding improvement for the higher grade distributions when compared with traditional courses, a significant decrease in the number of failing grades is noted. In traditional courses, this percentage ranges from fifteen to thirty percent. This suggests that the modules were particularly effective for those groups of students who are generally classified as slower achievers.

Results from the student attitude questionnaires were somewhat varied, but indicated a general positive opinion toward computer-based instructional materials and the use of the modules in organic chemistry.

Several student questionnaires were administered to the Fall 72 class. Similar questionnaires were also given early in the semester to the Spring 73 class and to classes that contained students who had transferred from the experimental class or who were repeating first semester organic chemistry in a traditional class, but who had been enrolled in the experimental class. Results are shown in Table V and Table VI.

Table V

Student Attidudes Concerning Computer-Based Lessons[a]

Item	Opinion (%)[b]				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Computer techniques are good study aids	3/2	3/2	2/2	54/57	37/33
2. The lessons have helped me to learn	3/0	2/2	9/13	53/57	33/27
3. I have enjoyed the lessons	11/5	5/8	22/21	36/55	26/10
4. I would use this type of study aid in other courses if it were available	7/4	5/0	28/13	40/68	19/14

[a]Voluntary anonymous responses were solicited from students immediately prior to final examination (56 responses), and either weeks after end of course (51 responses). Note that there may be some variation based on difference in students who chose to respond.

[b]% opinions tabulated as shown: $\frac{{}^{1}n}{{}^{2}n}$

where ${}^{1}n$ = % of 56 voluntary responses received prior to examination

${}^{2}n$ = % of 51 voluntary responses received 8 weeks after end of course

The data in Table V indicates that a majority of students felt computer techniques were good study aids, helped them learn organic chemistry, were enjoyable, and that they would use this form of study aid in other courses. As might be predicted from the positive shift in semester performance at the lower end of grade distributions, students who were enrolled in the experimental class, but who were repeating the first semester in a traditional class, were particularly positive in their response for this form of study assistance.

The data in Table VI indicates that students generally felt the computer-based lessons helped pace them through the course, were fair supplements toward learning organic chemistry, were enjoyable, and should be continued. In addition, they did not resent being a part of the experiment and did not look at the computer-based lessons as just another assignment to be completed.

Further student support for computer-based instruction is shown by the data in Table VII. All the students who had participated in the first semester experimental class, independent of whether or not they were continuing in this class, had transferred to a traditional course or were repeating the first semester in a traditional course, ranked the computer as a high contributer toward learning organic chemistry. A control group, with no prior use of computer-based instructional techniques, ranked the computer as the lowest potential contributor.

Table VI

Additional Questions for Formal University Student Evaluation (Anonymous and Voluntary) of Experimental Course and Instructor

For Following Questions

Answer:	Definitely Yes	Yes	Uncertain	No	Definitely No
	+2	+1	0	-1	-2

Did the use of computer-based instruction help you discover and use your own pace for learning organic chemistry:

$(\bar{X})^a = .4[.7](.8)$

Do two formal lectures per week plus regular computer-based lessons seem to provide sufficient explanation of subject matter for a self-paced introductory course in organic chemistry:

$(\bar{X}) = .7[.5](-.2)$

Is it fair to ask students to teach themselves organic chemistry from a selected textbook aided by formal lectures and computer-based lessons?

$(\bar{X}) = .2[.5](.8)$

If this course had been composed of three formal lessons per week and <u>optional</u> computer-based lessons, would you have devoted as much time to studying the computer-based lessons as you did this semester?

$(\bar{X}) = .4[.2](.2)$

Did you find working on the computer-based lessons an enjoyable way to learn organic chemistry?

$(\bar{X}) = .6[.8](1.0)$

Do you think it is accurate to say that the textbook presents an introduction to organic chemistry organized descriptively according to functional groups, while the formal lectures seem to present a broader, more theoretical organization according to organic structure and reaction mechanism?

$(\bar{X}) = .9[.8](1.0)$

Should a combination of computer-based instruction and formal lectures (such as used this semester) be used in future courses to help students learn organic chemistry?

$(\bar{X}) = .9[1.0](1.2)$

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[a] average responses indicated as ${}^1n[{}^2n]({}^3n)$

where ${}^1n$ shows average of 61 responses obtained immediately prior to final examination

${}^2n$ shows average of 52 responses obtained 8 weeks later both from students currently enrolled in second half of organic chemistry (818b) and from students repeating first half of organic chemistry

${}^3n$ shows average of 37 responses of students currently enrolled in 818b only

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For Following Questions

Answer:	most of the time	a good part of the time	some of the time	a small part of the time	never
	+2	+1	0	-1	-2

Have you resented being part of this experiment which is trying to define new ways of presenting subject matter in an introductory organic chemistry course?

$(\bar{X}) = -1.0[-1.2](-1.4)$

Were you able to correlate the two different organizational approaches used in the text and in formal lectures?

$(\bar{X}) = .4[.2](.5)$

If you think back over the feelings you had while completing the required computer-based lessons, do you believe you were usually trying to learn and understand the content of each lesson (instead of just trying to get through one more assignment)?

$(\bar{X}) = .5[.6](.8)$

Table VII

Student Ranking of Contribution to Learning of Organic Chemistry

Students were asked to:
Rank the following in the order which you feel would most contribute to learning organic chemistry. Rank the most important as No. 1 and the least important as No. 5.

_______Textbook
_______Formal lectures
_______Question and answer discussion period
_______Laboratory (including laboratory lecture)
_______Computer-based lessons

Averaging their responses for each item gave the following order (questionnaire administered before final examination):

1. Text
2. Computer
3. Lecture
4. Lab
5. Q-A Period

Average ranking on anonymous follow-up questionnaire (8 weeks after the final examination)

S_{SKB}*	K_{SB}	K_{KB} (control)	B_{SA}
1. text	1. text	1. lecture	1. text
2. lecture	2. lecture	2. text	2. lecture
3. computer	3. computer	3. Q-A period	3. computer
4. lab	4. Q-A period	4. lab	4. lab
5. Q-A period	5. lab	5. computer	5. Q-A period

*S_{SKB} = students from experimental group now taking second half of course (818b) with instructor of experimental course

K_{SB} = students from experimental group now taking second half of course (818b) with another instructor

K_{KB} = students with no exposure to experimental course, now enrolled in second semester (818b) with another instructor

B_{SA} = students from experimental group now repeating course (818a) with another instructor

Again, the results indicate a generally positive response toward computer-based instructional techniques, particularly in the educational value of the computer as a study aid.

V. COSTS

Cost records were kept for the following.

a) Computer charges for the organic chemistry lessons developed under Project C-BE
b) Computer charges involved in the revision of all organic chemistry lessons used in the three-semester study; and,
c) Computer charges for student use of the lessons.

The total computer charges for lesson development a[illegible]wn in Table VIII.

Table VIII

Computer Charges for Lesson Development

Lesson		Cost
OCH20		41.33
OCH24		35.67
OCH26		42.92
OCH28		97.94
OCH29		61.24
OCH30		24.30
OCH31		175.78
OCH32		120.11
OCH33		57.25
OCH34		41.92
	Total:	698.46

Differences in charges are a function of the length of the lesson and the number of computer compilations required in debugging the lesson prior to initial use.

Revision costs, primarily for the lessons used in the first semester of organic chemistry, are shown in Table IX. These costs include charges necessitated by hidden errors found after the initial debugging of a lesson and up-dating costs, such as re-setting the minimum achievement level in a given lesson.

Table IX

Revision Costs

Lesson	Cost
OCH1	45.48
OCH2	7.78
OCH3	11.61
OCH4	6.00
OCH6	31.40
OCH7	50.83
OCH10	20.63
OCH11	25.50
OCH12	11.62
OCH14	10.31
OCH16	9.65
OCH17	2.48
OCH18	7.82
OCH19	3.65
OCH22	26.37
Total:	271.14

Student use cost data are shown in Table X.

Table X

Time Required and Cost of Interaction

	Fall 72	Spring 73	Fall 73
Number of Jobs (sign-ons) Run	2,082	1,360	1,848
Hours of Computer Connect Time	1,489.89	771.67	1,213.22
Computer TM* Hours	7.21	4.09	7.10
Computer TM Charge	$1,875.10	$1,064.23	$1,845.18
Computer Connect Time Charge	$667.65	$308.67	$485.29
Cost Per Student-Terminal Hour	$1.71	$1.78	$1.92
Ratio Connect Time/TM	207/1	189/1	171/1

*TM hour includes central processing time and peripheral processing time.

VI. SUMMARY STATEMENT OF PROBLEMS ENCOUNTERED IN THE DEVELOPMENT OF C-BE MATERIALS

Within the developmental process per se, no major problems were encountered. Developing computer-based instructional materials is a time consuming task. This author estimates that, initially, 50-80 hours of developmental time were required for each hour of student interaction with a given program. After a degree of expertise in the design and developmental processes (program and computer system) had been attained, this number of developmental hours was reduced to about 20-40 hours.

In the early stages of development, most problems that arose were due to computer system downtime that resulted in losing several hours of work involved in creating a program. Slow response time and slow turn around time for a submitted program compilation were also early problems. Since this period, however, problems involving the computer system have been resolved to the extent that the above-mentioned difficulties rarely occur.

Based upon the experience gained in six years of developing computer-based instructional materials, the author submits the following suggestions and comments for consideration.

1) Do not program in languages that are highly machine dependent. A critical area of current concern is the transportation of computer-based instructional materials. Most large systems have their own version of a CAI-type language and often developed materials have become restricted to the originating site. Extended BASIC is probably the closest to a "universal" language.

2) If possible, develop each program as a self-contained module. This will allow a high degree of flexibility in application to meet varying instructional strategies, student needs, and instructor whims.

3) Avoid sterile programs; convey a degree of your own personal touch in responses. Students get tired of just "correct" or "incorrect" computer replies.

4) Avoid lengthy textual output. Often material can be displayed by computer-controlled random access slide projection. Use this if your system has the feature. If not, student hand-outs or similar printed materials should be used.

5) Make sure that the student knows what is expected of him and what the program does. State concise, clear, quantitative performance objectives at the beginning of the program or in accompanying printed materials.

6) Avoid linear programming. Branching strategies for varied student needs based on student input are one of the main strong-points for computer-based instruction.

7) Avoid lengthy programs. Gluteal limits are reached in about 30-45 minutes at the terminal. Again, modularize, if possible.

8) Design programs that are <u>supplements</u> to instruction. Successful computer-based instructional materials that <u>replace</u> a teacher or "traditional" course are essentially non-existent.

9) Follow a "systems approach" in the design, development, and evaluation of your materials. That is, (1) define the program, (2) define quantitative objectives, (3) task analysis and design of the instructional sequence (to this point, it's a mental, paper and pencil process), (4) construct the program; debug, (5) pilot test with 2-10 students, (6) revise based on feedback, (7) class use, (8) evaluation, (9) revision.

10) Document the program adequately, not only in terms of technical documentation, but also in terms of pedagogical applications. Include sample interactions.

11) Use all reference resource materials available.

12) Recognize the worth of the computer in instruction as a tool of extremely high potential, but no better (or worse) than the person(s) developing the program(s).

VII. PROCEDURES FOR INTRODUCTION AND USE

As was described earlier, these lessons were written in CLIC, a programming language unique to the University of Texas at Austin Computation Center. As such, the lessons have extremely limited transport potential. However, the concepts and instructional strategies involved in the lessons are more universal and may be encompassed by a variety of programming languages and computer systems.

The results of this study indicate that the best use of the modules is that in which they were originally designed, i.e., as supplements within the introductory organic chemistry course. The modular design of the lessons allows instructors to describe their use as best fit the needs of the student and the course.

VIII. TRANSFER

The organic chemistry programs were used during the 1973 Fall semester at Southwest Texas State University and the University of Texas at Permian Basin. Both universities utilized The University of Texas at Austin CDC 6600-6400 computer system. The universities continued using the program for their introductory course in organic chemistry during the Spring semester of 1974. Internal feedback from the course instructors was generally positive. The transfer was conducted by the NSF-sponsored Project CONDUIT at the University of Texas.

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